WATER QUALITY EVALUATION
OF
THE MINAKI AREA

Water Resources Assessment
Technical Support Section
Northwestern Region

April, 1976

Ministry
of the
Environment
Ontario

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BY

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
	1.1 DESCRIPTION OF STUDY AREA	1
2.0	METHODS	1
	2.1 SELECTION OF STUDY SITES	1
	2.2 PHYSICO-CHEMICAL	2
	2.3 SECCHI DISC - CHLOROPHYLL *a*	3
3.0	RESULTS AND DISCUSSION	3
	3.1 TEMPERATURE AND DISSOLVED OXYGEN	3
	3.2 CARBON DIOXIDE	5
	3.3 WATER CHEMISTRY	5
4.0	SECCHI DISC - CHLOROPHYLL *a*	12
5.0	BACTERIOLOGY	13
6.0	SUMMARY AND CONCLUSIONS	13
	RECOMMENDATIONS	15
	REFERENCES	16
	APPENDIX A	17
	GLOSSARY OF TERMS	18

1.0 INTRODUCTION

The Minaki area is presently the focal point of a multi-million dollar tourist development. Additionally, the area is part of a larger development plan for Lake of the Woods. The Ministry of Natural Resources has conducted a number of studies related to this development and it is in conjunction with these studies that the Ministry of the Environment has assessed water quality to determine local problems and constraints.

The following report provides the results of a survey conducted during June, July and August of 1975 and discusses them in terms of general water quality and trophic status.

1.1 DESCRIPTION OF STUDY AREA:

The study area is located approximately 20 air miles north west of Kenora in the unorganized District of Kenora.

The physical nature of the study area is characterized by exposed Precambrian granites overlain in some cases by thin glacial drift composed largely of sand and gravel. The watersheds of the study sites (Figure 1.1.1.) drain into the Winnipeg River, which is in the Hudson Bay drainage system.

Mean annual temperatures in the vicinity are between 0.5 and 2.2C, and annual precipitation is between 50 and 78 cm.

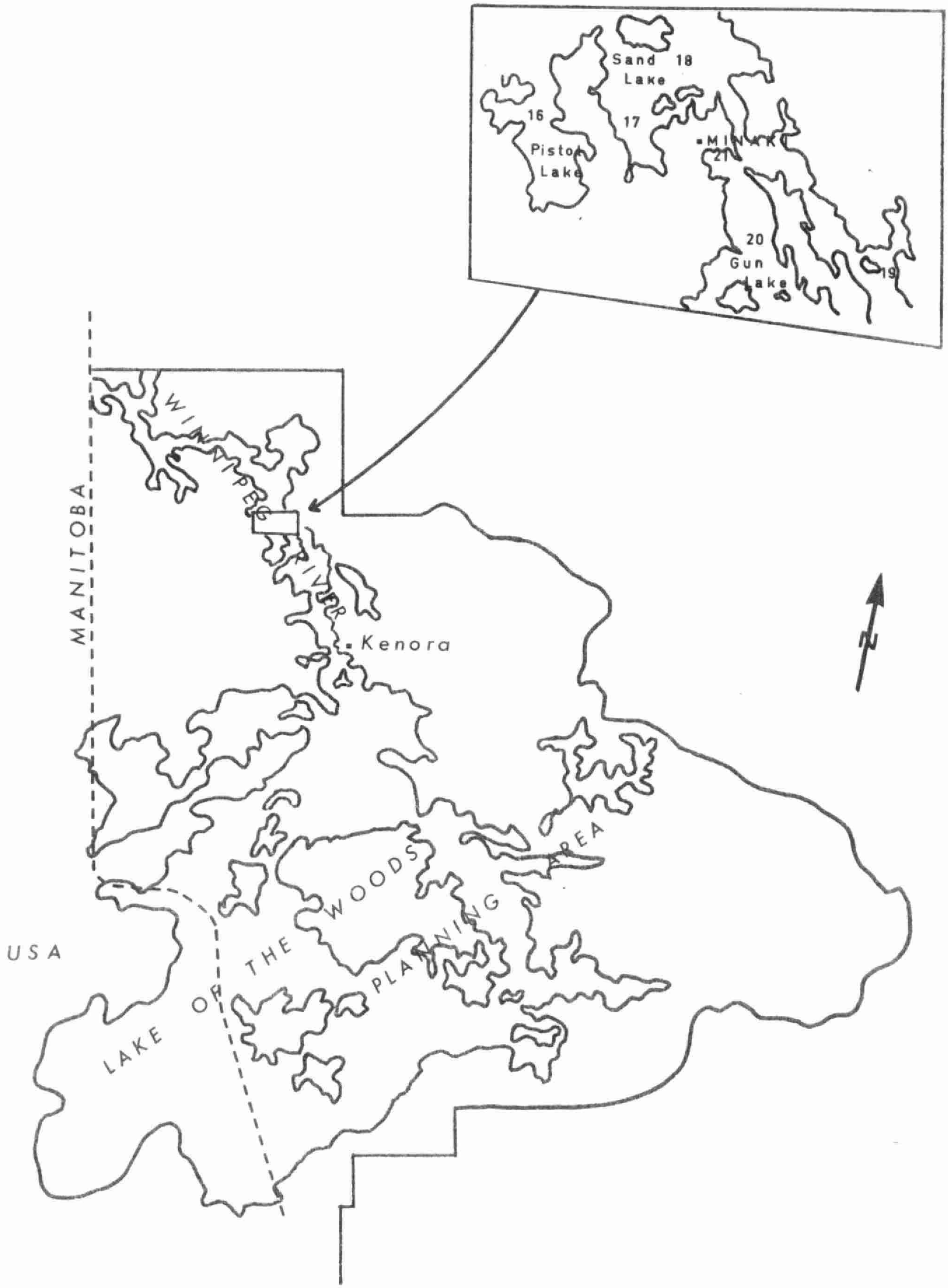
2.0 METHODS

2.1 SELECTION OF STUDY SITES:

The six study sites were selected on the basis of

FIGURE 1.1.1.

STUDY SITES



proximity to development.

Site 16, on Pistol Lake, is west of the village of Minaki and furthest removed from the river. Sites 17 and 18, on Sand Lake, are adjacent and north of the village. Site 19 is on the Winnipeg River upstream from the influence of the village. Sites 20 and 21 on Gun Lake, are adjacent to and south of the village.

2.2 PHYSICO-CHEMICAL METHODS:

The sites were visited on a two-week cycle, resulting in each being sampled five times. Duplicate one litre samples were collected at each depth and two depths (one metre below surface and one metre above bottom) were sampled at each location. Samples were stored in a portable cooler during transportation to the field laboratory where pH, alkalinity, acidity, and free CO_2 were determined. Subsequently, samples were shipped to the Regional Laboratory for analysis, including:

Conductivity (T.D.S.)	Iron
Hardness (Calcium and Magnesium)	Lead
Total Phosphorus	Zinc
Nitrogen compounds (TKN, NH_3, N_2, N_3)	Nickel
Sulphate	Copper
Colour	Cobalt
Turbidity	Cadmium
	Mercury

Additionally, one 150 ml sample was collected, one metre below the surface, at each location, for bacteriological analysis.

Oxygen and temperature regimes were determined directly in the field with a YSI model 54 oxygen-temperature meter.

2.3 SECCHI DISC - CHLOROPHYLL a:

Secchi disc readings measure the transparency of lake water to incident light by lowering a disc, 20 cms in diameter with alternate black and white quadrants into the water on the shaded side of the boat. The depth at which the disc disappears is noted as well as the depth at which it reappears. The mean of the two readings is termed the Secchi disc depth. This depth approximately corresponds to the lower limit of the euphotic zone. Vollenweider, 1969, found that twice the Secchi depth approximates the level of 1% incident light and this level has been found sufficient to support active photosynthesis by algae.

Chlorophyll a samples were collected in 1 litre glass bottles as composite samples from the euphotic zone. 300-1000 mls. of the sample were filtered through 1.2 µ 'Millipore' filter paper under a vacuum of approximately 1 Kg/cm^2 (14 P.S.I.). The filtered samples were placed in plastic containers covered in aluminum foil and stored at -15° to $-20^{\circ}C$. Chlorophyll a concentrations were later determined at the laboratory, by 90% acetone extraction and UV- visible spectrophotometry.

3.0 RESULTS AND DISCUSSION

3.1 TEMPERATURE AND DISSOLVED OXYGEN:

The temperature and dissolved oxygen profiles for the study sites are depicted in Figures 3.1.1. and 3.1.2.

The stability of the thermocline is extremely important in determining the vertical distribution of chemical species and dissolved gases in a lake since

FIGURE 3.1.2

DISSOLVED OXYGEN AND TEMPERATURE PROFILES 21/7/75

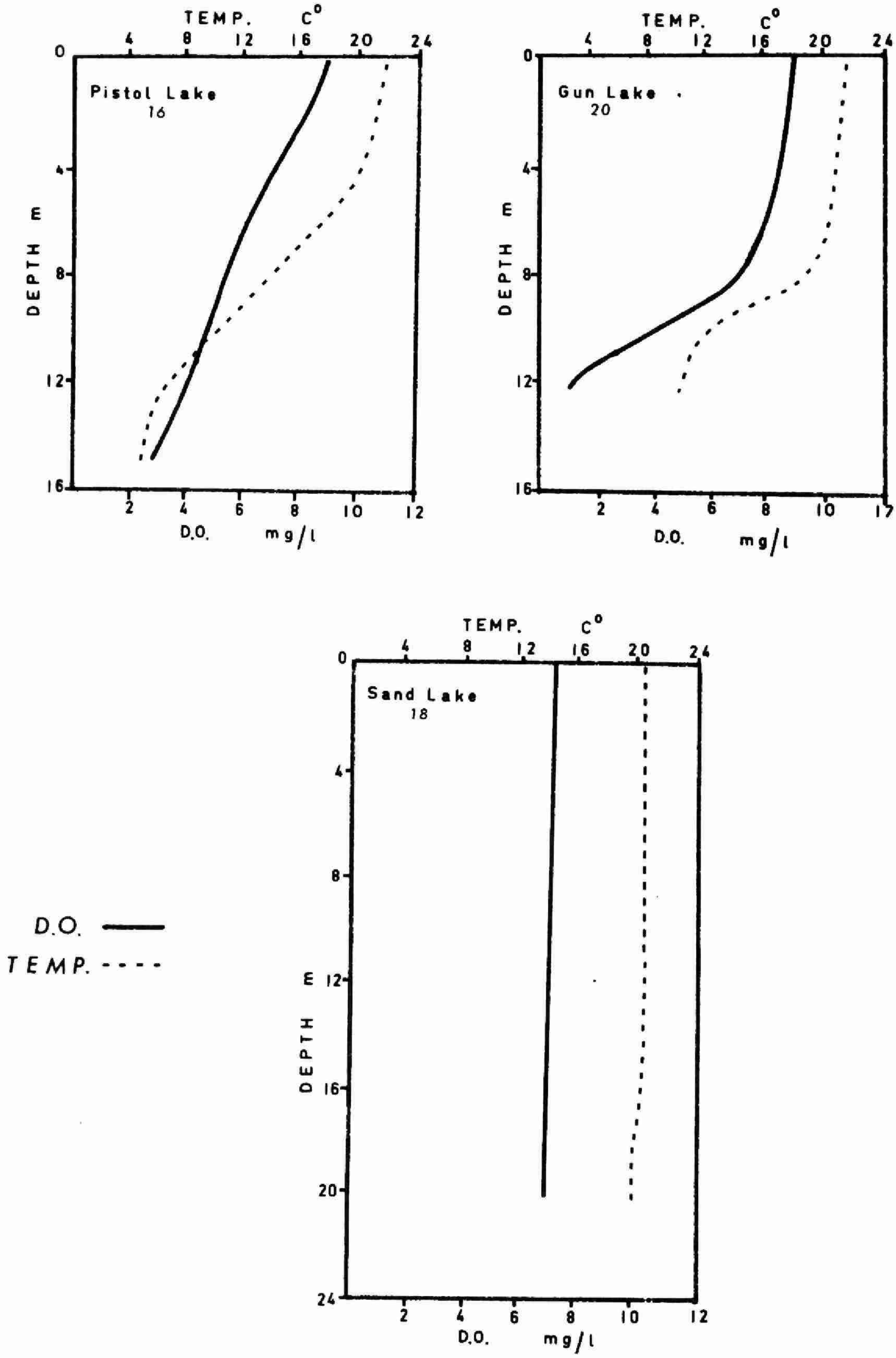
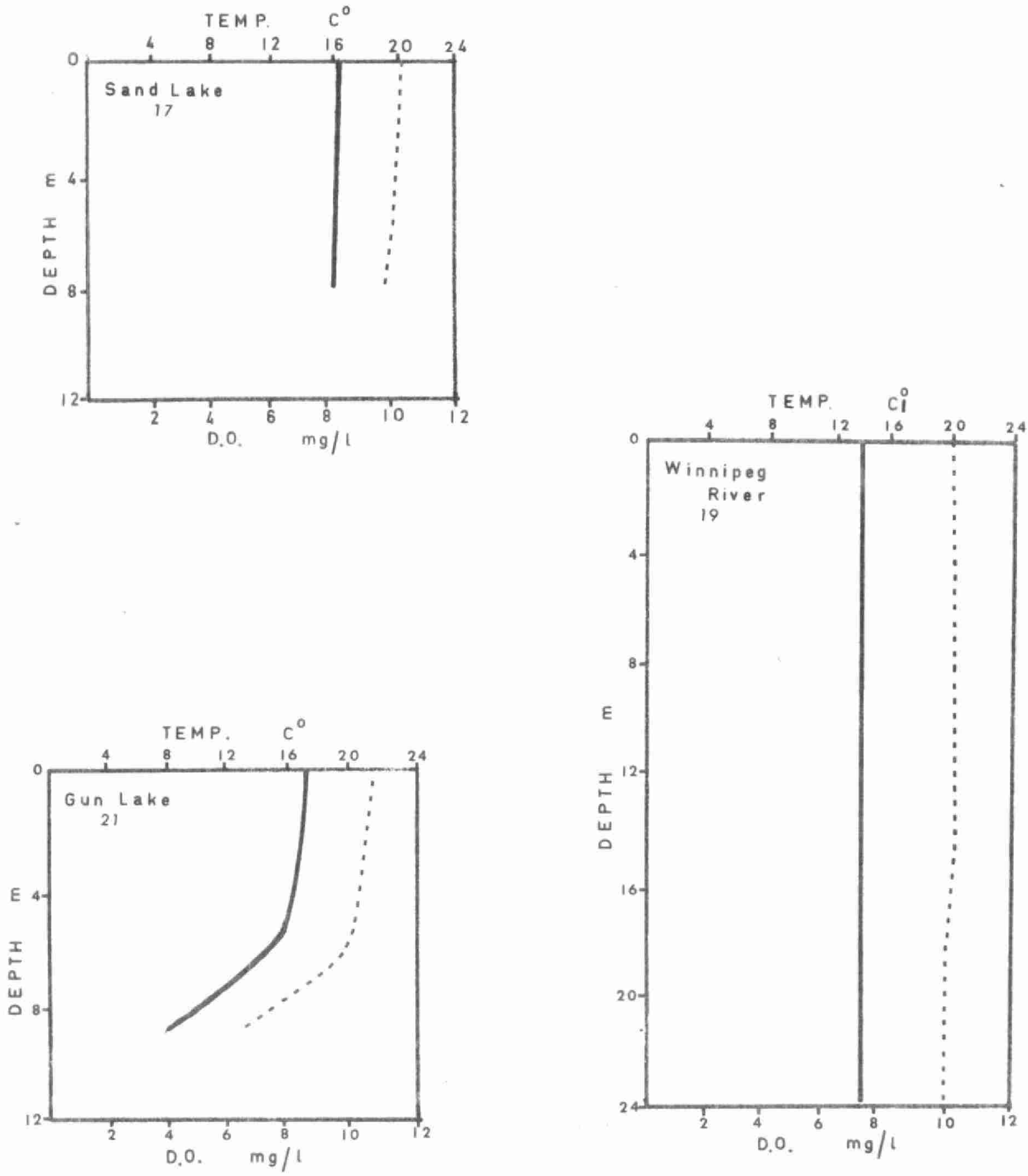


FIGURE 3.1.1.


TEMP. C°
4 8 12 16 20 24
Sand Lake
17
DEPTH m
0 4 8 12
2 4 6 8 10 12
D.O. mg/l
TEMP. C°
4 8 12 16 20 24
Winnipeg
River
19
DEPTH m
0 4 8 12 16 20 24
2 4 6 8 10 12
D.O. mg/l
TEMP. C°
4 8 12 16 20 24
Gun Lake
21
DEPTH m
0 4 8 12
2 4 6 8 10 12
D.O. mg/l

a well established thermocline effectively isolates the surface water (epilimnion) from the bottom water (hypolimnion) acting as a barrier to vertical diffusion. Sites 16, 20 and 21 exhibit a well defined thermocline, but little surface to bottom temperature change is exhibited by sites 17, 18 and 19 - an indication of mixing by current action.

Aquatic concentrations of dissolved oxygen are extremely important in a lake since fish and other aquatic life forms require oxygen for respiration.

The type of oxygen distribution found in a lake in mid-summer is the product of (a) production of oxygen by photosynthetic organisms in the presence of sunlight,
(b) depletion of oxygen by respiring organisms
(c) the stability of thermal stratification and
(d) absorption of oxygen from the atmosphere.

Extremely low concentrations of dissolved oxygen were recorded in the bottom waters of Gun Lake (1.4 mg/l and 4.0 mg/l) and Pistol Lake (2.6 mg/l). The low dissolved oxygen concentrations observed in the hypolimnia at these locations are of extreme concern as they are well below the level considered necessary for the survival of cold water fishes (5 to 6 mg/l - M.O.E., 1974). A further concern related to the observed low dissolved oxygen concentrations is the potential for the release of nutrients from bottom sediments under anaerobic conditions. This aspect is discussed in more detail under section 3.3.

Bottom water oxygen deficits and corresponding clinograde oxygen distributions at sites 16, 20 and 21, indicate substantial synthesis of nutrients into plant material and its subsequent decomposition at the expense of the oxygen resources in the hypolimnion. This reflects a vulnerability of these lakes to artificial inputs of domestic wastes (Brydges, 1971).

The orthograde distributions of sites 17, 18 and 19 signify that oxygen levels are fairly uniform from the

surface waters to the hypolimnetic waters as a result of current mixing.

3.2 CARBON DIOXIDE:

Carbon Dioxide (CO_2) is extremely important as a contributor to the "fitness" of natural waters. It serves in a more or less purely chemical sense to "buffer" the environment against rapid shifts in acidity-alkalinity states. The fact that the compound contains carbon, and as a result is responsible for the availability of this element for chemical combination, is paramount to the balancing of an aquatic ecosystem (Reid, 1961).

High CO_2 levels such as those found in the hypolimnion of Pistol and Gun Lakes, Table 1, Appendix A, are indicative of high acidity. This means that there is a greater potential for significant shifts in pH.

3.3 WATER CHEMISTRY:

The results of chemical analyses are provided in Table II to XI of Appendix A. A summary of ranges in concentration of selected parameters is provided in Table 3.3.1.

Phosphorus

The concentration of total exchangeable phosphorus (P) in natural waters is determined primarily by (1) basin morphometry as it relates to volume and dilution, and to stratification or water movements, (2) chemical composition of the geological formations of the area as they contribute dissolved phosphate, (3) drainage area features in relation to the introduction of organic matter; and (4) organic metabolism within the body of water, and the rate at which phosphorus is lost to

TABLE 3.3.1.

RANGES IN CONCENTRATIONS OF SELECTED VARIABLES

MINAKI AREA, 1975

	SITE 16	SITE 17	SITE 15	SITE 19	SITE 20	SITE 21
pH	6.7-7.6	7.2-7.4	7.2-7.5	7.1-7.4	6.9-7.9	7.0-7.9
Alkalinity	37.1-39.0	41.8-46.1	41.5-48.1	41.2-46.7	42.8-46.7	43.0-50.3
Acidity	2-10	2-4	2-5	3-5	1-12	1-7
Conductivity	93-96	104-106	104-106	104-105	103-106	103-107
Total Dissolved Solids	60.5-62.4	67.6-68.9	67.6-68.9	67.6-68.3	67.0-68.9	67.0-69.6
Calcium	13-14	16	15-16	15-16	15-16	15-16
Magnesium	8	9	9-11	9-11	9-11	9-11
Hardness	42-43	49	47-50	47-51	47-49	48-50
Total Phosphorus	.011-.037	.018-.032	.019-.025	.016-.079	.016-.046	.017-.062
Total Kjeldahl	.30-.57	.38-.57	.33-.57	.35-.94	.34-.69	.36-.72
Free Ammonia	<.01-.08	<.01-.07	<.01-.05	.02-.06	<.01-.04	<.01-.06
Nitrite	.002-.005	.002-.004	.002-.004	.002-.005	.002-.006	.002-.005
Nitrate	<.01-.07	<.01	<.01	<.01	<.01-.05	<.01-.03

Sulphate	3-5	3-8	3-5	3-9	4-9	3-6
Colour	15-40	15-40	30-40	15-40	15-60	15-60
Turbidity	0.8-1.8	1.1-1.7	1.1-1.9	1.1-1.6	0.8-4.6	0.9-4.7
Iron	.03-.14	.05-.08	.05-.10	.05-.07	.05-.15	.06-.07
Lead	<.004	<.004	<.004	<.004	<.004	<.004
Zinc	.002-.021	<.002-.023	.002-.023	.002-.026	<.002-.022	.019-.022
Copper	<.002-.011	<.002-.009	<.002-.014	<.002-.004	<.002-.007	.004-.005
Nickel	<.002-.026	<.002-.008	<.002-.004	<.002-.012	<.004-.010	.002-.004
Cobalt	<.004	<.004	<.004	<.004	<.004	<.004
Cadmium	<.001	<.001	<.001	<.001	<.001	<.001
Mercury	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06

All units are in mg/l except:

pH - pH units

Conductivity - umho/cm

Colour - Hazen Units (H.U.)

Turbidity - Formazin Turbitity Units (F.T.U.)

the sediments (Reid, 1961).

It has been indicated (Michalski and Conroy, 1973) that troublesome levels of algae can be expected to materialize when mean total phosphorus concentrations during the ice-free season exceed .020 mg/l. With the exception of the surface water in Pistol Lake (.017 mg/l) phosphorus concentrations at all stations are in excess of the above criterion.

Brydges, 1971, has shown that under anaerobic conditions nutrients, particularly phosphorus, may be released from sediments into bottom waters. The ratio of total iron to total phosphorus in the bottom waters provides an indication of the extent of this recycling process. Low ratios indicate a significant degree of recycling, while high ratios indicate that significant recycling is not occuring. A summary of iron to phospohorus ratios at sites in the study area, exhibiting anaerobic conditions in their bottom waters, is presented in Table 3.3.2.

TABLE 3.3.2:

Fe:P Ratios

Location	Fe:P Ratio
Site 16	9.3
Site 20	3.5
Site 21	2.6

As indicated in Table 3.3.2, iron to phosphorus ratios at these sites were low - lower than the value (10.1) reported by Michalski, Johnson and Veal, 1973, for Gravenhurst Bay, an area demonstrating severe eutrophication problems.

Nitrogen and Nitrogen Compounds

The importance of nitrogen in aquatic ecosystems rests upon its role in the synthesis and maintenance of protein.

Little organic nitrogen is available as nutrient for plants and animals. As a consequence, measurements of inorganic nitrogen compounds (ammonia, nitrate, nitrite) are felt to be a better measure of productivity (Reid, 1961). In most fresh waters the concentrations of these inorganic compounds are relatively low; as is the case at the study sites. Ammonia and nitrate ranges fall below detection limits and the nitrate range is just above the detectable limit. The high total kjeldahl nitrogen (T.K.N.) indicates that much of the nitrogen is tied up in organic material.

Conductivity

The conductivity of natural waters is mainly owing to the presence of calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulphate and nitrite ions.

The watershed of the study sites drains a relatively soluble geological substrate and conductivities ranging from 93-107 umho/cm are consistent with this. Nearby Lake of the Woods has a mean summer specific conductivity of 100 umho/cm (Armstrong & Schindller, 1971).

Specific conductance is related to the total dissolved solids (T.D.S.) concentration. Ontario rivers and lakes, free of cultural wastes, have a T.D.S. generally equal to 0.65 ± 0.10 times the specific conductance.

Calcium and Magnesium

Together, these two elements constitute the most

abundant ions in fresh waters. The chemical activity of each is similar, particularly in the formation of carbonate salts and both may limit biological processes.

Calcium is generally present in all natural waters at levels which depend on the amount of contact with specific geological formations. The concentrations at the study sites are consistent with Armstrong and Schindler's findings on Lake of the Woods (Mg - 14 mg/l, Ca - 4 mg/l) which drains the same type of substrate.

Magnesium is present in all natural waters and is associated with the presence of calcium. In waters containing more than 50 mg/l T.D.S. they are, on the average, in a ratio of 3:5 respectively (Reid, 1961).

In the presence of normal calcium concentrations, the concentrations of carbonic acid produced during biological activity remains low and normal values for alkalinity are obtained. This is the result of free acid being bound up with calcium to form $CaCO_3$.

pH

pH is a measure of the hydrogen ion concentration in water. Specifically, it is the negative logarithm of the free hydrogen ion concentration expressed in moles per litre. Since a change of one unit in pH corresponds to a 10-fold change in the hydrogen ion concentration, small shifts in pH can be critical to species habitat.

Hypolimnetic decreases in pH, such as those exhibited in Pistol and Gun Lakes, are the result of carbonic acid formation. This condition indicates that there is an instability in the water's capacity to balance concentrations of acid and base. This instability is a further indication that the potential exists for shifts in pH.

Acidity

The acidity of water is a measure of its capacity to neutralize a base. The major acidic component of natural waters is carbonic acid which is obtained by the atmospheric absorbtion of carbon dioxide or by the release of carbon dioxide as a metabolic by-product.

The higher acidity values obtained for the hypolimnion of Pistol and Gun Lakes indicate that their buffering capacity is weak.

Alkalinity

The alkalinity of water is a measure of its capacity to neutralize acid. In neutral waters the major component of alkalinity is the bicarbonate ion which may be formed by the action of dissolved carbon dioxide on limestone or other calcium deposits.

Although alkalinity is reported as mg/l of $CaCO_3$, this does not necessarily imply that there is this much calcium carbonate in the water, or that there is any at all.

The alkalinity of the water is generally used to define the capacity of the water to buffer pH changes. This means that if an acidic waste is discharged to a natural system, the effect on the water may not necessarily be detected as a pH change, but will be detected as a drop in alkalinity.

Normal values for alkalinity at the study sites indicate that the water has the ability to buffer against acid discharges, to a certain extent, without registering a change in pH.

Sulphur

The most frequently encountered forms of sulphur

in fresh waters are as the anion sulphate (SO_4). It is ecologically important in natural waters in several ways: (1) necessary for plant growth, (2) required for protein metabolism and (3) instrumental in the liberation of phosphate under anaerobic conditions (Reid, 1961).

Sulphate concentrations usually vary between 10 and 80 mg/l in natural waters. Levels such as those obtained for the study sites are consistent with other bodies of water in the area (Armstrong and Schindler, 1971).

Under anaerobic conditions, sulphates serve as an oxygen source for bacteria which converts it to hydrogen sulphide gas.

Turbidity

Turbidity, measured in Formazin Turbidity Units (F.T.U.), is the term used to describe the degree of opaqueness produced in water by suspended particulate matter. While the nature of the materials contributing to the turbidity is mainly responsible for the colour quality, the concentration of the substances, if sufficiently high, determines the transparency of the water by limiting the light transmission. This aspect is of considerable importance, especially as it relates to productivity and energy flow within the aquatic community. The values for the study sites are low, indicating a viable euphotic zone.

Colour

Colour, measured in Hazen Units (H.U.), is primarily associated with the presence of humic acids derived from the decomposition of organic material.

Only the apparent colour is reported since it is considered more representative of field conditions. Apparent colour includes the colour owing to dissolved substances as well as the additional colour contributed by suspended matter.

The study sites exhibit a range from 15 to 60 H.U. These values are completely acceptable by the MOE objective of $<$75 H.U. for public surface water supplies. However, the fact that highly coloured water is considered unacceptable is based solely on aesthetic considerations and not on known health hazards.

Metals

Water analysis for the following list of heavy metals indicated that, for the study lakes, levels are low or detectible levels are absent.

(1) Iron
(2) Lead
(3) Zinc
(4) Copper
(5) Nickel
(6) Cobalt
(7) Cadmium
(8) Mercury

The low concentrations of these elements can be attributed to their short residence times in natural waters. As soon as they enter the system they are absorbed to organics and minerals.

Trace levels exist for the majority of heavy metals (unsubstantiated in this study) with a contributed benefit to the environment. However, high concentrations of these elements often create a condition of toxicity to aquatic communities.

4.0 SECCHI DISC - CHLOROPHYLL a

The results of chlorophyll a - Secchi disc monitoring are provided in Table XII, Appendix A. Mean values for the study sites are provided in Table 4.0.1.

TABLE 4.0.1:

MEAN SECCHI DISC AND CHLOROPHYLL a DATA
MINAKI AREA, 1975

SITE	SECCHI DISC DEPTH (m)	CHLOROPHYLL a ($ug\ l^{-1}$)	NO. OF SAMPLES
16	3.3	2.9	6
17	2.6	4.9	6
18	2.7	3.7	6
19	2.8	3.7	6
20	2.6	4.7	6
21	2.7	3.9	6

Vallentyne, 1969, reported that lakes with Secchi disc transparencies of less than 3 metres are eutrophic while lakes exhibiting Secchi disc readings exceeding 6 metres are oligotrophic. By this criterion all of the sites, with the exception of Pistol Lake are eutrophic. Pistol Lake with a mean Secchi disc reading of 3.3 metres is in an advanced stage of mesotrophy. This parameter, alone, is not a means of categorizing bodies of water. Before judgement is passed on the status of a study area, several corroberating parameters must be present.

The concentration of chlorophyll a, the main photosynthetic green pigment in plants, provides an indication of the extent of biological activity in a lake. As indicated in Table 4.0.1., mean concentrations

of chlorophyll a at the study sites ranged from 2.9 to 4.9 ug/l. The highest concentrations of chlorophyll a occured at the sites exhibiting the lowest Secchi disc readings and vice versa.

Experience has indicated that chlorophyll a values below 5 ug/l, indicate low to moderate algae densities characteristic of oligotrophic lakes. All of the study sites fall into this category.

Studies by the MOE indicate that a hyperbolic relationship exists between chlorophyll a concentrations and Secchi disc transparencies. This relationship can be used to bracket the trophic status of a lake. Figure 4.0.2. represents this relationship graphically with the values for the study sites included. From this graph it is evident that the study sites fall within the mesotrophic range.

5.0 BACTERIOLOGY

The survey indicated that the bacteriological water quality of the study sites in 1975 was good (Table XIII, Appendix A) and was within the Ministry of the Environment's Microbiological Criteria for Total Body Contact Recreation i.e.

> "Where ingestion is probable, recreational waters can be considered impaired when the coliform, faecal coliform and faecal streptococcus geometric mean densities exceed 1000, 100 and 10 per 100 ml respectively, ..."

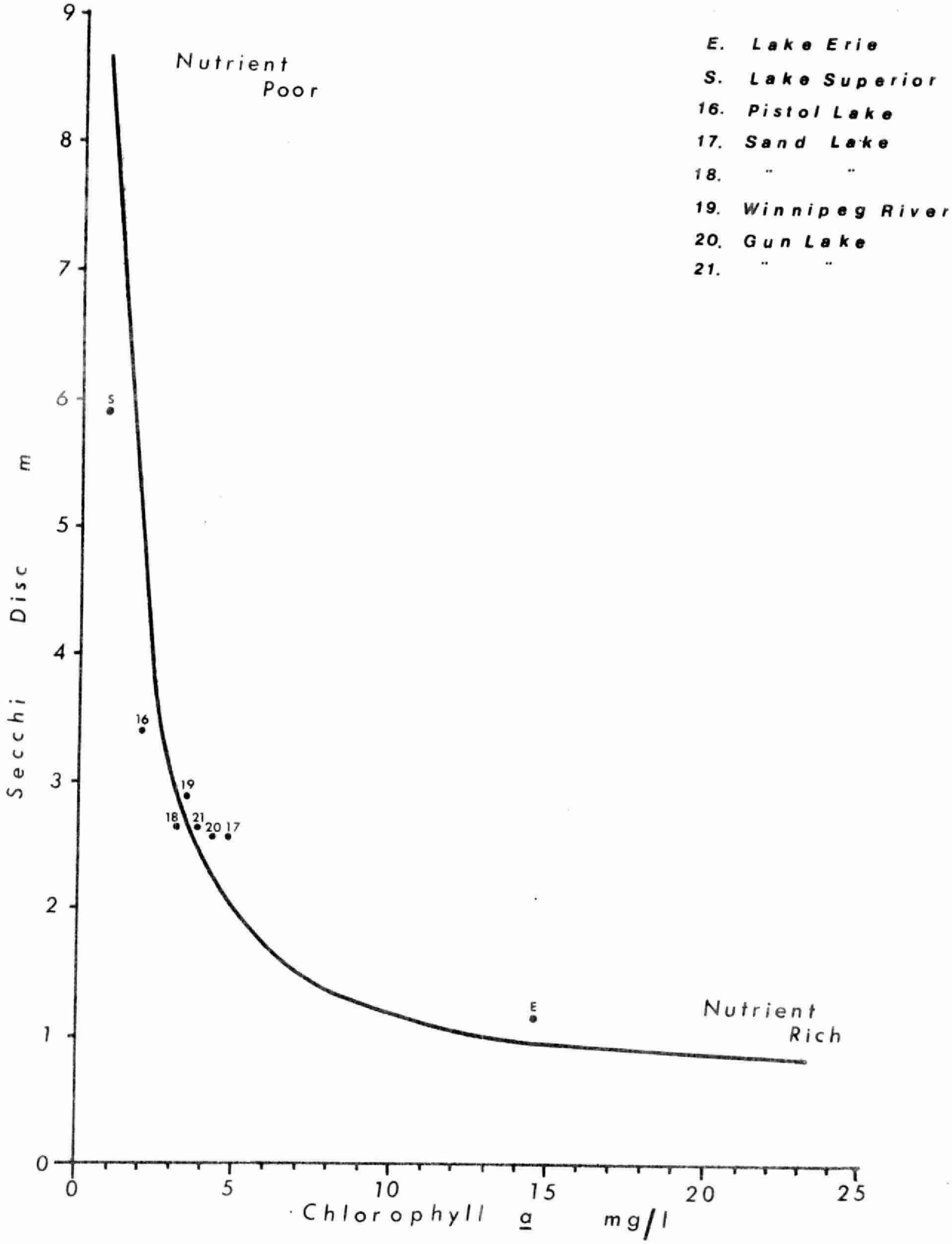
6.0 SUMMARY AND CONCLUSIONS

The waterways in the vicinity of Minaki are representative of both lentic (still waters) and lotic environments (moving waters).

The sites on Pistol and Gun Lakes exhibit

FIGURE 4.0.2.

THE RELATIONSHIP BETWEEN CHLOROPHYLL a
SECCHI DISC AS DETERMINED FROM
ONTARIO LAKES



mid-summer stratification and an accompanying gradient of physico-chemical parameters (lentic). The chlorophyll a - Secchi disc relationships and clinograde oxygen distributions are interpreted as mesotrophic - a condition lying between unproductive (oligotrophic) and highly productive (eutrophic). The high total phosphorus levels and low iron to phosphorus ratios indicate a potential for excessive aquatic plant and algae growth. Under conditions of low oxygen levels, the accumulation of plant nutrients, particularly phosphorus, creates the existence of a potential for nuisance levels of aquatic plants and algae.

The high CO_2 and acidity values in conjunction with hypolimnetic decreases in pH indicate a weakness in the buffering capacity. This demonstrates a susceptibility of the sites to artificial inputs of nutrients.

The sites on Sand Lake and on the Winnipeg River exhibit the ameliorating influence of the current (lotic). There is a thorough mixing and moving of the waters with a moderating effect on physico-chemical parameters. Each site has a chlorophyll a - Secchi disc relationship which falls within the limits of the mesotrophic state and the chemical climate is unstratified. For these lotic waterways, no water quality problems were revealed by the study.

RECOMMENDATIONS

1. In the study area development should be carefully planned and should incorporate appropriate controls for the protection of water quality.

2. Disposal of domestic wastes should be regulated by MOE criteria to ensure continued suitability of the waters in the area for recreational use.

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APPENDIX: A

TABLE I Carbon Dioxide (CO_2) Concentrations (mg/l)
1 metre below the surface and 1 metre above bottom

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	1.4	6.0	2.1	2.4	2.1	1.6	2.7	2.3	1.9	3.7	0.5	1.2
23/6/75	3.0	6.4	3.1	3.6	3.4	4.2	2.5	3.4	3.2	5.3	1.6	3.1
7/7/75	1.8	6.3	3.1	3.5	---	---	2.7	3.5	1.1	5.7	1.2	6.1
21/7/75	2.2	7.3	2.9	3.3	2.8	3.2	3.3	2.6	1.8	6.7	1.8	2.2
17/8/75	4.4	8.8	3.4	3.1	3.5	3.9	3.9	3.9	2.7	10.1	2.0	4.8
9/9/75	---	---	---	---	---	---	---	---	---	---	---	---
Mean	2.6	7.0	2.9	3.2	3.0	3.2	3.0	3.1	2.1	6.3	1.4	3.5

TABLE II Total Phosphorus (P) (mg/l)

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	----	----	----	----	----	----	.016	.022	.030	.025	.029	.026
23/6/75	.018	.037	.032	.024	.026	.025	.025	.028	.031	.023	.028	.023
7/7/75	.026	.035	.032	.024	----	----	.030	.079	.019	.016	.017	.032
21/7/75	.014	.017	.019	.018	.019	.028	.025	.026	.029	.046	.018	.025
17/8/75	.011	.015	.027	.027	.028	.026	.026	.020	.028	.040	.017	.062
9/9/75	----	----	----	----	----	----	----	----	----	----	----	----
Mean	.017	.026	.028	.023	.024	.026	.024	.035	.027	.030	.022	.034

TABLE III Range of Concentrations for Nitrogen Compounds (mg/1)

COMPOUND	SITE 16	SITE 17	SITE 18	SITE 19	SITE 20	SITE 21
TKN	.30-.57	.38-.57	.33-.57	.35-.94	.34-.69	.36-.72
NH_3	< .01-.08	< .01-.07	< .01-.05	.02-.06	< .01-.04	< .01-.06
NO_2	.002-.005	.002-.004	.002-.004	.002-.005	.002-.006	.002-.005
NO_3	< .01-.07	< .01	< .01	< .01	< .01-.05	< .01-.03

TABLE IV Conductivity - Total Dissolved Solids

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	COND. (umho cm/1)	T.D.S. (mg/1)	COND. (umho cm/1)	T.D.S. (mg/1)	COND. (umho cm/1)	T.D.S. (mg/1)	COND. (umho cm/1)	T.D.S. (mg/1)	COND. (umho cm/1)	T.D.S. (mg/1)	COND. (umho cm/1)	T.D.S. (mg/1)
10/6/75	93	60.5	106	68.9	105	68.3	104	67.6	103	67.0	103	67.0
23/6/75	94	61.1	105	68.3	106	68.9	105	68.3	105	68.3	106	68.9
7/7/75	96	62.4	105	68.3			105	68.3	105	68.3	107	69.6
21/7/75	94	61.1	104	67.6	104	67.6	104	67.6	106	68.9	106	68.9
17/8/75	94	61.1	105	68.3	105	68.3	104	67.6	104	67.6	105	68.3
9/9/75	--		---		---		---		---		---	
Mean	94	61.2	105	68.3	105	68.3	104	67.9	105	68.0	105	68.5

TABLE V Calcium and Magnesium Concentrations (mg/l)

DATE	SITE 16			SITE 17			SITE 18			SITE 19			SITE 20			SITE 21		
	HARD.	Ca	Mg	HARD.	Ca	Mg	HARD.	Ca	Mg	HARD.	Ca	Mg	HARD.	Ca	Mg	HARD.	Ca	Mg
10/6/75	43	14	8	49	16	9	50	16	10	51	16	11	49	16	9	49	16	9
23/6/75	43	14	8	49	16	9	49	16	9	49	16	9	49	16	9	49	16	9
7/7/75	42	13	8	49	16	9	--			48	15	11	48	15	11	50	16	10
21/7/75	43	14	8	49	16	9	47	15	10	47	15	10	47	15	10	48	15	11
17/8/75	43	14	8	49	16	9	48	15	11	49	16	9	49	16	9	51	16	11
9/9/75	--			--			--			--								
Mean																		

TABLE VI Range of pH

DEPTH	SITE 16	SITE 17	SITE 18	SITE 19	SITE 20	SITE 21
1 metre below surface	7.1-7.6	7.2-7.4	7.2-7.4	7.2-7.4	7.3-7.9	7.7-7.9
1 metre above bottom	6.7-7.0	7.2-7.4	7.2-7.5	7.1-7.4	6.9-7.1	7.0-7.8

TABLE VII Acidity ($CaCO_3$) Concentration (mg/l)
1 metre below surface and 1 metre above bottom

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	2	6	2	3	2	2	3	3	2	4	1	1
23/6/75	3	4	4	4	4	5	3	4	4	6	2	4
7/7/75	2	7	4	4	-	-	3	4	1	7	1	7
21/7/75	3	8	3	4	3	4	4	3	2	8	2	3
17/8/75	5	10	4	4	4	5	5	5	3	12	2	6
9/9/75	-	-	-	-	-	-	-	-	-	-	-	-
Mean	3	7	3	4	3	4	4	4	2	7	2	4

TABLE VIII Alkalinity ($CaCO_3$) Concentration (mg/l)

DATE	SITE 16	SITE 17	SITE 18	SITE 19	SITE 20	SITE 21
10/6/75	38.6	46.1	48.1	46.1	45.8	50.3
23/6/75	37.1	45.1	45.4	45.8	----	----
7/7/75	39.0	45.2	----	45.6	46.0	45.9
21/7/75	38.3	46.1	46.7	46.7	46.7	48.4
17/8/75	37.2	41.8	41.5	41.2	42.8	43.0
9/9/75	----	----	----	----	----	----
Mean	38.0	44.9	45.4	45.1	45.3	46.9

TABLE IX Sulphur (SO_4) Concentration (mg/l)
1 metre below surface and 1 metre above bottom

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	-	3	5	5	5	5	5	5	5	5	5	5
23/6/75	4	4	4	3	3	3	3	3	4	4	4	3
7/7/75	4	4	7	8	-	-	4	9	9	5	5	5
21/7/75	4	4	4	5	5	5	5	5	5	5	6	6
17/8/75	5	5	5	5	5	5	5	5	5	4	4	5
9/9/75	-	-	-	-	-	-	-	-	-	-		

TABLE X Turbidity (F.T.U.)
1 metre below surface and one metre above bottom

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	1.0	1.3	1.2	1.2	1.3	1.3	1.2	1.2	1.2	2.7	1.2	1.2
23/6/75	1.7	1.8	1.3	1.3	1.1	1.3	1.3	1.4	1.3	2.3	1.5	1.3
7/7/75	0.8	1.1	1.2	1.1			1.1	1.6	0.8	1.6	0.9	2.4
21/7/75	1.0	1.6	1.3	1.6	1.4	1.9	1.5	1.5	1.2	4.6	1.1	1.9
17/8/75	1.0	1.5	1.6	1.7	1.3	1.6	1.6	1.4	2.3	2.3	1.7	4.7
9/9/75	---	---	---	---	---	---	---	---	---	---	---	---

TABLE XI Colour (H.U.)
1 metre below surface and 1 metre above bottom

DATE	SITE 16		SITE 17		SITE 18		SITE 19		SITE 20		SITE 21	
	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM	SURF	BOTTOM
10/6/75	30	30	30	30	30	30	30	20	20	30	30	30
23/6/75	20	20	40	30	30	30	30	30	30	30	30	30
7/7/75	15	15	15	15	--	--	15	15	15	15	15	15
21/7/75	30	30	30	30	30	30	30	30	30	30	30	30
17/8/75	40	40	40	40	40	40	40	40	40	60	40	60
9/9/75	--	--	--	--	--	--	--	--	--	--	--	--

TABLE XII Transparency - Chlorophyll a Relationship

DATE	SITE 16 SECCHI DISC DEPTH(m)	SITE 16 CHLORa (mg/1)	SITE 17 SECCHI DISC DEPTH(m)	SITE 17 CHLORa (mg/1)	SITE 18 SECCHI DISC DEPTH(m)	SITE 18 CHLORa (mg/1)	SITE 19 SECCHI DISC DEPTH(m)	SITE 19 CHLORa (mg/1)	SITE 20 SECCHI DISC DEPTH(m)	SITE 20 CHLORa (mg/1)	SITE 21 SECCHI DISC DEPTH(m)	SITE 21 CHLORa (mg/1)
10/6/75	3.0	2.5	2.4	3.7	2.5	2.9	2.8	3.6	2.5	3.3	2.8	3.4
23/6/75	3.5	1.6	2.5	2.3	2.8	1.9	2.8	2.4	2.8	2.1	2.5	2.3
7/7/75	3.6	3.1	2.9	3.9	2.9	2.1	2.8	5.0	3.0	2.4	3.4	2.1
21/7/75	3.3	3.5	3.0	4.5	2.9	--	3.0	3.5	2.7	3.8	2.8	3.4
17/8/75	3.5	2.2	2.2	6.0	2.6	5.1	2.5	4.4	2.6	7.8	2.8	4.4
9/9/75	3.0	4.7	2.4	8.8	2.6	6.3	2.9	3.5	2.2	8.7	2.1	8.0
Mean	3.3	2.9	2.6	4.9	2.7	3.7	2.8	3.7	2.6	4.7	2.7	3.9

TABLE XIII Bacteriology Geometric Means (/100 ml)

SITE	COLIFORM	FAECAL COLIFORM	FAECAL STREPTOCOCCI
16	10	0	5
17	40	0	2
18	65	0	0
19	32	0	0
20	13	0	0
21	61	3	0

GLOSSARY OF TERMS

ALGAE	- an assemblage of simple, mostly microscopic plants. Although these plants lack stems, roots and leaves all contain the photosynthetic green pigment chlorophyll.
ANAEROBIC	- a condition where little or no oxygen is present.
CLINOGRADE	- a type of vertical oxygen distribution where there is a decrease in oxygen levels with depth.
EPILIMNION	- the uppermost region of warm, homothermal water in a lake.
EUPHOTIC ZONE	- the lighted region that extends vertically from the water's surface to the level at which photosynthesis fails to occur because of ineffective light penetration.
EUTROPHIC ("rich food")	- a condition in which a lake is considered highly productive.
HYPOLIMNION	- the bottom region of cool, homothermal water in a lake.
MESOTROPHIC	- a condition in which a lake is considered moderately productive.
OLIGOTROPHIC	- a condition in which a lake is unproductive.
ORTHOGRADE	- a type of vertical oxygen distribution where there is a relatively uniform oxygen level from surface to bottom.
THERMAL STRATIFICATION	- with the progression of the summer season the resistance to mixing between regions of different density (resulting from increased temperatures) become greater than the force of winds. As a result three density defined regions are established.

THERMOCLINE - a region of rapid temperature drop located between the epilimnion and hypolimnion.

TROPHIC STATUS - depending on the degree of plant nutrient enrichment and resulting biological productivity, lakes are generally classified into three types: oligotrophic, mesotrophic and eutrophic.